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LOCKING INTRAMEDULLARY NAILING WITH PRIMARY SOFT TISSUE RECONSTRUCTION IN HIGH GRADE OPEN TIBIAL FRACTURES

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MADURAI.

CERTIFICATE

This is to certify that the dissertation entitled **"LOCKING INTRAMEDULLARY NAILING WITH PRIMARY SOFT TISSUE RECONSTRUCTION IN HIGH GRADE OPEN TIBIAL FRACTURES"** is a bonafide record of work done by ***Dr. S. JAWAHAR*** in the Department of Orthopaedics, Government Rajaji Hospital, Madurai Medical College, Madurai, under the direct guidance of me.

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<u>DECLARATION</u>

I, **Dr. S. Jawahar,** solemnly declare that the dissertation entitled "**LOCKING INTRAMEDULLARY NAILING WITH PRIMARY SOFT TISSUE RECONSTRUCTION IN HIGH GRADE OPEN TIBIAL FRACTURES "** has been prepared by me under the able guidance and supervision of **Prof. M. Chidambaram, M.S.ORTHO., D. ORTHO., Prof & HOD,** Department of Orthopaedics and Traumatology, Madurai Medical College, Madurai, in partial fulfillment of the regulation for the award of **M.S. (ORTHOPAEDICS)** degree examination of The Tamilnadu Dr. M.G.R. Medical University, Chennai to be held in March 2008.

This work has not formed the basis for the award of any other degree or diploma to me previously from any other university.

Place : Madurai

Date :

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CONTENTS

INTRODUCTION

A severe open tibial fracture is the result of high energy violence. The operative management is complex, time consuming and considered by many to create a significant morbidity. Many of the problems are related to the unique anatomy of tibia with its vulnerable soft tissue envelope.

The type of treatment depends on the individual characteristics of the fracture and the concomitant soft tissue injury making experience and clinical judgement an important part of overall treatment.

The established management of severe open tibial fracture is based on a philosophy of initial wound debridement and lavage, stabilization of fracture with external fixation and delayed wound closure. Debridement may need repeating because of the difficulty assessing tissue viability. Soft tissue cover is delayed to allow for a healthy wound bed.

Though external fixator is easy to apply and has limited effect on the blood supply of tibia, these advantages have been overweighed by the high incidence of pin tract infection, difficulties in soft tissue managements like flap mobilization and potential for malunion & nonunion.

Godina's[1] proposed use of early flaps to cover large wounds and the shift from external to internal fixation has led to the development of more radical approach to these devastating injuries.

With a potent antibiotic cover and advances in fracture stabilization, soft tissue reconstruction procedures and better wound care, primary skeletal stabilization with interlocking intramedullary nailing and primary soft tissue reconstruction has been gaining acceptance.

Early reports of this aggressive 'fix and flap' protocol[2] points towards faster union time and lower infection rate as the vascularised flap tissues rapidly and reliably converts the severe open fracture to a closed injury in a single stage, acting as a biological dressing, protecting the bare tibia devoid of periosteum from destructive nosocomial strains.

Hence we conducted a prospective, randomized study comparing the outcomes of locking intramedullary nailing and primary soft tissue reconstruction with that of external fixation and delayed soft tissue reconstruction, at our Government Rajaji Hospital, Madurai.

AIMS AND OBJECTIVES

1. To study the anatomical and functional outcome of management of open tibial fractures with locking intramedullary nailing and primary soft tissue reconstruction.

2. To do a prospective, randomized, control study comparing the outcomes of locking intramedullary nailing and primary soft tissue reconstruction with that of external fixation and delayed soft tissue reconstruction.

3. To study the various methods of soft tissue reconstruction.

REVIEW OF LITERATURE

1983 – Velazco et al[3] reported the use of the Lottes nail in a series of 50 open tibial fractures and noted a 6% deep infection rate and a malunion rate of only 4%.

1985 – Court – Brown and Hughes[4] obtained worse results with static external fixator and believed it led to a higher delayed and nonunion rate than other treatments. Complications unique to external fixation were pintract infection and pin loosening, which occur in up to 50% of patients. Loss of frame stability is a recognosed entity and may account for the higher malunion rate of upto 45% with external fixation.

1986 – Chapman[5] (1986), Wiss (1986) and Holbrook et al[6] (1989), the latter in a prospective study, used ender type unreamed nails successfully in the treatment of open tibial fractures with low rates of postoperative infection.

1989 – Holbrock et al[6] reported on a randomized comparison of Ender's nails and external fixation in open fractures. The authors reported a decreased incidence of infection in the Ender's nail group (7%) versus external fixation (14% deep, 4% superficial, and 21% pin site sepsis).

1990 – Swanson et al[7] compared the Lottes nail with external fixation and reported infection rates of 6% in the nailing group and 7% in the external fixation group. The malunion rate was 27% and 24%, respectively.

1990 – G.G. Russell et al[8] reported that the incidence of deep infection was 20% after primary wound closure compared with 3% after delayed closure and eight of the nine non-unions followed primary closure. They concluded that primary wound closure should be avoided in the treatment of open fractures.

1991 – Court – Brown et al[9] analysed 41 Gustilo type II and III open fractures treated with nailing and documented a mean union time of 33.2 weeks with a 9.7% incidence of infection, 4.9 malunion, and 36.3% nonunion. The mean time to union was comparable with the results of external fixation in the same institution but the malunion rate and need for bone grafting were much lower.

1994 – Tornetta et al[10] conducted a prospective, randomized, control trial comparing unreamed intramedullary nailing with external fixation for III B open tibial fractures and concluded that nailing was preferable because of easier management and increased patient satisfaction.

1997 – Keating et al[11] conducted a study “Reamed interlocking intramedullary nailing of open fractures of tibia” and conducted that nailing is a safe and effective concluded technique for management of open tibial fractures.

1998 – Henley et al[12] suggested that interlocking intramedullary nails are more efficacious than half-pin external fixators, in particular with regard to maintenance of limb alignment, fewer subsequent procedures and a lower rate of infection.

1999 – Delong et al[13] did not find immediate closure (with in 24 hours) to be associated with a higher rate of infection or non-union when compared with delayed closure at more than 24 hours.

1999 – Hertel et al[14] performed a retrospective study of open tibial fractures and found that immediate coverage was associated with a lower rate of infection (0/14) when compared with late coverage (4/14), reduced number of re-operations, and decreased time of definitive union and proposed that early closure of thoroughly debrided wound is safe.

2000- Keating et al[15] in his study indicated that reamed intramedullary nailing is a satisfactory treatment for Gustilo grade – III tibial fractures.

2000 – Gopal et al[2] retrospectively reviewed the results associated with 84 type III B and C open tibial fractures and reported lower rates of infection as well as shorter time to union when compared the outcomes of early closure (24 to 72 hours) and late closure (more than 72 hours).

2001 – Bhandari M et al[16] systematically reviewed the effect of alternative methods of stabilization open tibial fractures and the rates of reoperation, and the secondary outcomes of nonunion, deep and superficial infection, failure of the implant and malunion by the analysis of 799 citations on the subject, identified from computerized databases. The use of unreamed nails, compared with external fixators, reduced the risk of reoperations, malunion and superficial infection.

2005 – Petrisor B et al[17] in a case series review of infections after reamed intramedullary nailing concluded that a number of deep infections after reamed tibial nailing are avoidable and correct soft tissue closure may help to reduce the incidence of infection after reamed nailing of open tibial fractures.

2006 – Naique Pearse, Nanchahal et al[18] compared the outcome of patients presenting directly to a special centre (where combined orthopedic and plastic surgery intervention available) with that of patients initially managed at local center (tertiary group). They reported increased complications and revision surgery encountered in tertiary group and suggested that severe open tibial fractures should be referred directly to specialist centres for simultaneous combined management by orthopedic & plastic surgeons.

2007 – Lawrence et al[19], in their analysis of surgeon controlled variables in treatment of limb threatening Type III open tibial fractures, reported that fractures that was treated with an external fixators had more surgical procedures, took longer to achieve full weight bearing and had more readmissions for treatment of infection & non-union than did those in whom the fracture was treated with an intramedullary nail.

SURGICAL ANATOMY

The tibia, with its asymmetric surrounding soft tissues, determines the shape of the lower part of the leg. Its roughly triangular external cross section has an anteriorly directed apex. Its anteromedial subcutaneous surface has no muscular or ligamentous attachments from the level of pes anserinus tendons and tibial collateral ligament of the knee to the deltoid ligament of the ankle[20].

Open fractures occur more often in the tibia because of the general lack of soft tissue coverage, making contamination a common concern in tibial intramedullary nailing. Furthermore, displacement of open tibial fracture fragments leads to periosteal stripping of the anterior tibial surface, rendering this exposed cortical bone avascular. Soft tissue closure or coverage of the fracture, rarely a problem in the thigh, is a major concern in the leg.

The proximal and distal ends of tibia

The proximal tibial metaphysis, with its medial and lateral tibial plateaus, is much larger in diameter than the shaft but is similarly triangular in cross section. Its anterior apex forms the tibial tubercle with the attached patellar ligament. Also apparent is the apex-anterior angulation of the proximal end of the tibia, which averages 15°. The backward-sloping, but variably shaped anterior surface of the tibial metaphysis offers a more or less obvious surface for inserting an intramedullary nail. The cancellous bone of the proximal metaphysis can be perforated fairly easily to gain access to the medullary canal. However, the shape of the proximal end of the tibia, its posterior overhang, and its thin, flat posterior wall make it possible to err and perforate the posterior cortex.

Distally, the shaft flares and becomes more rounded as it undergoes a transition from diaphysis to metaphysis. The cortex thins, and the fatty medullary contents are replaced with cancellous bone that is surprisingly dense. This cancellous bone provides secure purchase for screws and is often compact enough to resist penetration by an intramedullary nail.

The contour of the distal end of the tibia is notable for a somewhat pronounced concavity on its anteromedial surface. Restoring this distal medial concavity is an essential part of closed reduction of distal tibial shaft fractures.

Medullary canal

The medullary canal of tibia extends from the cancellous bone of the proximal metaphysis to that of the distal metaphysis. If the canal were extended proximally along its axis, it would enter the lateral plateau because of the relatively greater medial overhang. The largest sagittal dimension of the proximal end of the tibia is also laterally located. Buehler and associates pointed out that for both these reasons, a lateral entry site for an intramedullary nail, anterior to the lateral intercondylar eminence, is least likely to deform a proximal fracture[21]. The diaphyseal canal is significantly more round in cross section than the external appearance of the tibia would suggest. Unlike the femur, it is more hourglass shaped than tubular, with a variably pronounced isthmus. Even after intramedullary reaming, a snug fit for an intramedullary nail can be obtained only in the middle few centimeters of the tibia. This limitation adversely affects the stability of proximal and distal fractures fixed with a nail. In the young, the medullary canal tends to be narrow. With aging and osteoporosis, the cortex becomes thinner, the metaphyseal cancellous bone becomes less dense, and the internal diameter of the medullary canal increases.

A thick interosseous membrane connects the lateral crest of the tibia to the anteromedial border of the fibula. Its major fibers run downward and laterally. This membrane is often largely intact after indirect torsional fractures of the tibia, and according to Sarmiento, Latta, and others, it is the major constraint to shortening of such injuries.

The tibia and fibula are surrounded by soft tissues that are most important in any consideration of injuries to this region. In fact, surgeons who pay more attention to the bones than to these soft tissues may commit irretrievable errors in evaluating and treating fractures of the tibia and fibula. The soft tissue envelope of the leg is injured to a greater or lesser extent whenever a fracture occurs. Open wounds are usually obvious, although they may be small and may under-represent the extent of damage within.

Compartments of the leg

The deep fascia of the leg envelops it circumferentially and is adherent to the tibia along its anteromedial surface, as well as proximally and distally, except for narrow passages for tendons and neurovascular structures. The cylinder thus formed is subdivided into four well-defined longitudinal compartments by septa that attach along the fibula. An anterolateral septum divides the lateral compartment from the anterior one, a posterolateral septum lies between the lateral and superficial posterior compartments. Finally, a posterior septum intervenes between the deep and superficial posterior compartments.

Familiarity with the cross-sectional anatomy of the leg is essential for fracture surgeons. Such knowledge aids in the physical examination, facilitates surgical approaches, and helps avoid injury to neurovascular and tendinous structures during insertion of percutaneous pins and wires.

The anterior compartment contains the dorsiflexors of the ankle and toes: the tibialis anterior, the extensor hallucis longus, and the extensor digitorum communis along with the accompanying peroneus tertius. Its neurovascular bundle consists of the anterior tibial artery and veins, joined in the proximal part of the compartment by the deep peroneal nerve.

The lateral compartment, superficial to the fibula, contains the peroneus brevis and longus muscles, the evertors of the foot. The peroneus longus begins proximally on the lateral aspect of the fibular head. The common peroneal nerve passes under this muscle at the point where it covers the neck of the fibula. The superficial peroneal nerve, which provides sensory input from the remainder of the dorsum of the foot and motor function to the peroneus muscles, lies within the lateral compartment, but no major vascular structures are present.

The superficial posterior compartment contains the triceps surae, or the primary ankle flexors consisting of the gastroenemius, soleus, and plantaris muscles. The sural nerve lies between layers of the posterior fascia of this compartment and provides sensation to the lateral aspect of the heel. No major artery lies within this compartment, which is the most distensible and least likely to have elevated pressure after injury.

The deep posterior compartment lies underneath (anterior to) the superficial compartment and distal to the popliteal line, with its muscles applied to the posterior surfaces of the tibia, the interosseous membrane, and the fibula. Within it lie the posterior tibial vessels and the tibial nerve, which provides motor function to the compartmental and plantar intrinsic muscles and sensory input from the sole of the foot. Also present are the peroneal vessels. The muscles in the deep posterior compartment are the flexor digitorum longus medially, the flexor hallucis longus laterally, and deep to these muscles, the tibialis posterior.

Blood supply

The diaphyseal blood supply typically reaches the tibia byway of a single nutrient artery, a proximal branch of the posterior tibial artery. After passing through the most proximal portion of the tibialis posterior, it obliquely enters the tibial shaft on its posterior surface in the proximal portion of the middle third of the bone, It is easily injured by displacement of a fracture through its long cortical foramen. Within the medullary canal, it courses proximally and distally and anastomoses with the metaphyseal endosteal vessels. A displaced fracture of the diaphysis is thus likely to devascularize the shaft downstream from the nutrient artery. If peripheral soft tissues are also significantly stripped, the entire vascular supply can be lost over a distance of several centimeters. Combined loss of the medullary and periosteal blood supply interferes with fracture healing and places the tibia at risk for post-traumatic osteomyelitis.

Through its intraosseous distribution, the medullary arterial system of the tibia provides nourishment to most of the uninjured diaphysis. Only the peripheral fourth to third of the diaphyseal cortex is supplied by anastomosing periosteal vessels. This fact is of special significance after reaming for an intramedullary nail because the combined devascularization caused by both the fracture and reaming produces a layer of necrotic bone through much of the diaphysis. The medullary arterial circulation regenerates in a few weeks in the space that exists around a medullary nail. This arterial regeneration permits revascularization of the inner cortical bone, which is also supported by recruitment of periosteal collateral circulation if the surrounding soft tissues are healthy enough.

After a fracture, the tibial blood supply changes dramatically. Peripheral vessels are recruited to take over much of the arterial supply of the cortex and revascularize necrotic areas, as well as provide nourishment for the metabolically active peripheral callus. This process requires healthy surrounding tissue and is most effective in areas with muscles closely applied to the tibia. Surfaces that are covered only with periosteum, subcutaneous tissue, and skin are less able to benefit from this temporary extraosseous blood supply. Viable attached muscular pedicles are thus crucial for segments of a fractured tibia and should be preserved during surgical exposure for debridement or fixation.

MECHANISM OF INJURY

Tibial fractures have many causes, ranging from simple falls with twisting forces to severe injuries. It is important to distinguish between high and low energy transfer.

For the tibial shaft fracture, a significant amount of energy must be applied in one of three modes.

Torsional injuries (eg. Skiing injuries) are more common with low energy trauma where the foot becomes fixed and the body rotates about this fixed point. These injuries produce a typical spiral fracture with little soft tissue injury.

Direct violence or high energy trauma occur as a result of motor vehicle accidents and industrial injuries, where high concentration of energy is applied over a small area with resulting increased damage to bone and soft tissues.

Stress fractures of tibia are caused by repeated loading with ultimate failure in fatigue mode.

CLASSIFICATION OF TIBIAL SHAFT FRACTURES

Classification system of fractures enables us to communicate more accurately and to make better diagnostic and therapeutic decisions, and they facilitate comparison of clinical and laboratory research results. As with all other fractures tibial diaphyseal fractures can be classified in a number of ways.

Gustilo and Anderson classification of Open fractures[22]

Attempts to define the severity of open wounds established an unquestioned relationship between wound severity and complications such as infection, problems with union, and rate of amputation. The classification of open fractures as described by Gustilo and Anderson[22] and later modified by Gustilo, Mendoza and Williams[23] is the most frequently quoted system in the literature. It is probably the most widely understood and accepted classification.

Type I	Clean wound of less than 1cm in length
Type II	Wound larger than 1cm length without extensive soft tissue damage, flap or avulsion

Type III	Wound associated with extensive soft tissue damage
	Open segmental fractures
	Traumatic amputation
	Gunshot injuries
	Farmyard injuries
	Fractures associated with vascular injury
Type III	Wounds are subdivided according to the amount of periosteal damage and requirement for vascular surgery.
Type IIIA	Adequate periosteal cover
Type III B	Presence of significant periosteal stripping
Type IIIC	Vascular injury requiring repair

Gustilo and colleagues specify that open fractures resulting from high energy or high velocity trauma, with segmental fractures or severe comminution, should be classified as type III injuries regardless of size of the wound.

Interobserver agreement in grading open tibial fractures according to Gustilo and colleagues' classification was investigated by Brumback and Jones[24]. They found an approximately 60% agreement about the grading of individual fractures. Consensus was better regarding the most severe or most minor extremes.

Tscherne emphasized on grading the severity of soft tissue damage in closed as well as open injuries. **Tscherne's grading system for open fractures**[25] uses wound size, contamination, and fracture pattern.

Grade I- Fractures have a small puncture wound without skin contusion, negligible bacterial contamination, and a low energy fracture pattern.

Grade II - Fractures have small skin and soft tissue contusions, moderate contamination, and variable fracture patterns.

Grade III- Fractures have heavy contamination, extensive soft tissue damage, and often, associated arterial or neural injuries. All fractures accompanied by ischemia and severe bone comminution belong in this group, as well as those associated with compartment syndrome.

Grade IV- Fractures are incomplete or complete. Amputations defined as separation of all important anatomical structures, especially major vessels and total ischemia.

The AO/ASIF classification for soft-tissue injuries uses a combination of the alpha - numeric fracture classification system and an IMN system wherein the injury to the integument (I), muscle (M), and nerve (N) is each judged independently. This classification system has several potential benefits for clinical research; however, it is cumbersome in clinical situations.

The **Hannover open-fracture classification,** developed by Sudkamp et al is based on a point-scale system for bone injury, soft-tissue injury, vascular injury, and contamination. Open fractures are classified as typed I through IV.

In 2006, Rajasekaran et al, Proposed the Ganga hospital severity score (GHS) proposal for predicting the salvage and outcome in Gustilo III A & III B open tibial fractures, taking into consideration the lacunas in Gustilo Anderson’s classification, such as under represented damage of muscles and bones, poor agreement rate, failure to address the question of outcome, decision of salvage etc. They classified the score into four groups. Group I – 1-5, Group II – 6-10, Group III-11-15, Group IV-16-20 and proposed that outcomes can be predicted with the help of these groups. A cut off score of above 14 has high sensitivity and specificity for amputation.

Table 1 – Open injury Severity Score

Covering Structures : Skin and Fascia	Score
Wound not over the bone No skin loss With skin loss	 1 2
Wound over the bone No skin loss With skin loss/Friction burns/ Degloving over the bone Circumferential wound with bone circumferentially exposed	 3 4 5
Functional Tissues : Musculotendinous & Nerve units	
Exposed musculotendinous (MT) units without injury Repairable injury to MT units Crushing with loss / Irreparable injury to MT units / Repairable nerve injuries Loss of one compartment of MT units / Irreparable nerve injuries Loss of two or more compartments / Subtotal amputation	1 2 3 4 5

Co – Morbid Conditions **Add 2 points for each condition present** 1. Open injury > 12 Hrs. **2.** Sewage or organic contamination / farmyard injuries **3.** Age > 65 yrs **4.** Debilitating diseases (DM, COPD, IHD etc) **5.** Fat embolism **6.** Associated systemic injuries **7.** Another major injury to the same limb / Compartment syndrome	

COMPLICATIONS OF TIBIAL SHAFT FRACTURES

Complications are common after fractures of the tibia and fibula and may be related to the fracture or to its management. Many different treatment modalities for tibial fractures are devised to avoid the complications.

Following are the usual complications:

Infection

The incidence of infection of the wound in patients who have an open fracture correlates directly with the extent of soft tissue damage.

For type I fractures- 0-2%, type II 2-7%, type III Overall- 10-25% (type III A- 7%, III B - 10-50%, III C – 25- 50 % with a rate of amputation of 50% or more).

Infection after Intramedullary Nailing

If an infected tibial fracture remains satisfactorily stabilized by an intramedullary nail and if the infection can be controlled, it may be best to continue with intramedullary stabilization until the fracture is healed.’ If an abscess is present, it must be drained, and such a finding suggests the need for removal of the nail and reaming of the medullary canal.

Court-Brown et al[27] subdivided infections associated with intramedullary nailing into three groups. In group one patients, presentation was early and there was no evidence of pyogenic collection. These fractures healed with antibiotics only. In group two patients, there was an abscess and these patients were treated by drainage and exchange reamed nailing. In group three, patients presented late and required extensive debriderient and bone and soft tissue reconstruction.

Superficial wound infections

Superficial wound infections occasionally develop during open treatment of closed fractures, as well as after open tibial injuries. Definition and diagnosis are important because trivial treatment of a deep infection is usually ineffective. Adequate deep cultures are essential for wounds with any indication of infection extending below the subcutaneous tissue. Some infections are undoubtedly superficial, although the burden of proof is on the treating surgeon.

Malunion

Most surgeons believe that the tibia should be restored to its original alignment after fracture and only minor degrees of malalignment should be accepted. The significance of residual deformity after union of tibial fracture is uncertain. Puno and others have pointed out that location of the deformity is important. Kettlekemp and colleagues demonstrated abnormal joint loading as a result of tibial deformity, more with varus than valgus. Some patients with deformity are symptomatic. For symptomatic patients with significant deformity an osteotomy is the appropriate treatment.' An alternative to osteotomy is the use of ilizarove technique. Less than 5 degrees of varus valgus angulation, less than to degrees of anteroposterior angulation, less than 15 degrees of rotation, and less than 15mm of shortening is generally accepted.

Delayed union

The term delayed union describes an ununited fracture that continues to Show progress towards healing or has not been present long enough to satisfy an arbitrary time criteria for nonunion. It is essential for the surgeon to recognize delayed healing, search for causes, and make appropriate decisions about treatment.

The causes for delayed union may be occult infection. poor local blood supply. bone loss, excessive mechanical instability and insufficient functional use.

Continued weight bearing in an appropriate brace or cast will often lead to union of a fracture that has been treated closed or with intramedullary nail. If the fracture is stable, dynamization can promote union in 50% or so of cases. Fibular osteotomy has been recommended as a stimulus for tibial fracture union. It is not very successful and may also increase instability and deformity.

Nonunion

Generally nonunion is said to be present when a minimum of nine months has elapsed since surgery and the fracture has shown no visible progressive signs of healing for three months. The classical signs of nonunion are pain at the fracture site associated with motion. The radiographs may show an obvious persistent fracture line. But the surgeon may have to use CT or bone scan to confirm the presence of nonunion. Intramedullary nails make the diagnosis of nonunion difficult as they abolish the pain and movement at the fracture site.

The principle causes of nonunion are infection, soft tissue damage resulting in impaired vascularity, excessive fracture site mobility, bone loss and gap between fragments and soil tissue interposition.

Aseptic nonunions can be treated by reamed nailing or exchange nailing. Atropic nonunions may require bone grafting. Partial fibulectomy is rarely required. Other methods of treatment include electrical stimulation, autologoues bone marrow injection, osteogenic proteins and llizarov technique which is particularly useful if nonunion is associated with shortening and malalignment.

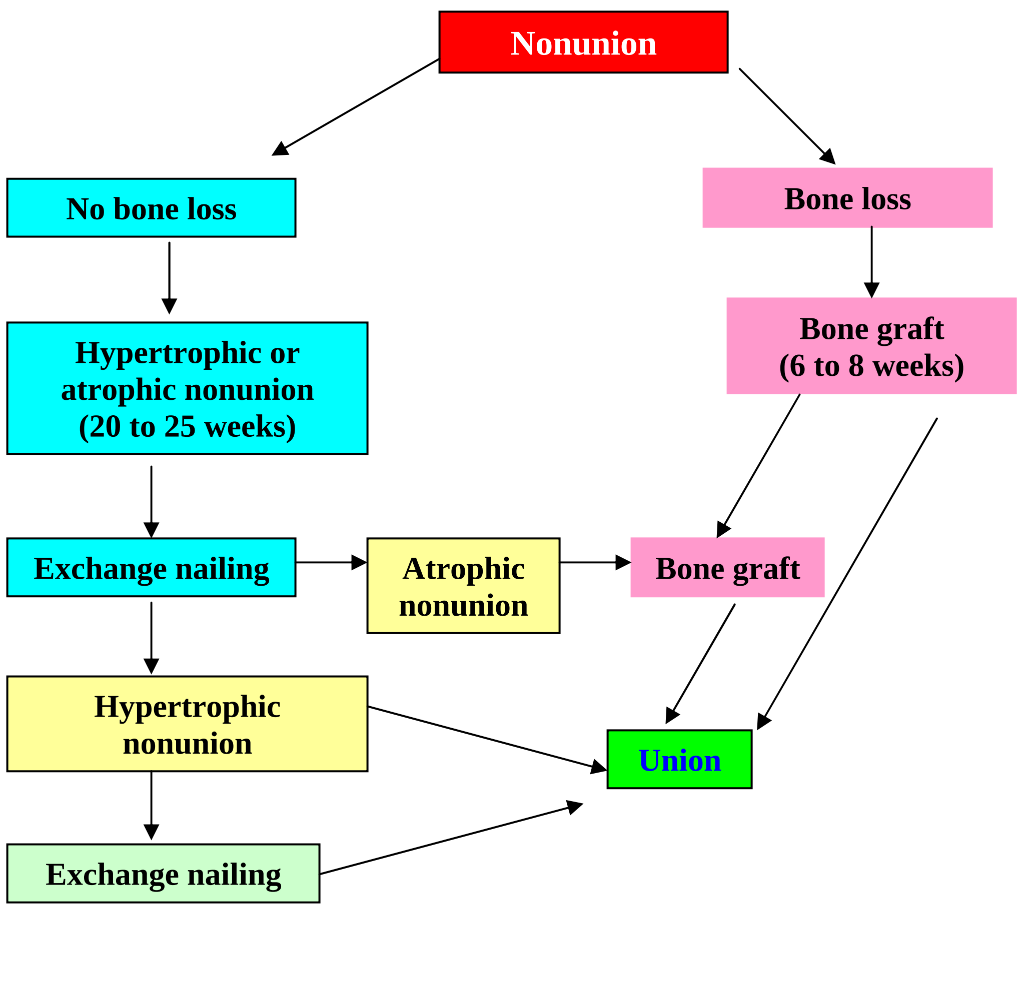
Infected nonunion

Posttraumatic osteomyelitis is one of the most feared of all the complications of tibial diaphyseal fractures. Some infected tibiae will unite although they are rarely asymptomatic with an episodic discharge from the bone. Most infected tibial fractures do not unite and infected nonunion results.

The principles of treatment of infected nonunion are: aggressive debriderient of all infected and devitalized bone and soft tissues. Fracture stabilization is achieved with an external fixator or an intramedullary nail; the soft tissues are closed using an appropriate plastic surgery technique, usually a muscle flap, free flap, or a fasciocutaneus flap; and the bone defect is filled with bone graft, bone transportation or acute bone shortening and subsequent lengthening. Appropriate antibiotic is given. Antibiotic impregnated beads deliver antibiotics to the infected site.

Other complications: Compartment syndrome, Reflex sympathetic dystrophy, Nerve injury, Vascular injury, Bone loss, Joint stiffness etc.,

MANAGEMENT NONUNION IN GUSTILO GRADE III-B FRACTURES TREATED BY INTRAMEDULLARY NAILING



SURGICAL TECHNIQUES

A) INTERLOCKING INTRAMEDULLARY NAILING

Preoperative planning

The length and diameter of nail were deduced preoperatively with the help of clinical measurements and radiographs of the uninjured tibia. The length was calculated from measuring tibial tubercle-medial malleolar distance (TMD). The TMD was determined by measuring the length between the highest (most prominent) point on the medial malleolus and the tibial tubercle. The diameter of the nail was assessed by measuring the tibia at its narrowest point, best appreciated on lateral roentgenograms.

Surgical procedure

Patients were operated under spinal / epidural / epidural general anaesthesia. Patient was placed in supine position over a radiolucent operating table. The limb was painted and draped so that full access was available from the knee joint to the ankle joint. The injured leg was allowed to hang freely by the side of the table with knee joint flexed at ninety degrees.

A vertical incision, about five centimeters long, extending from tibial tubercle upwards was applied. After incising subcutaneous tissue and fascia, the patellar tendon was either split or retraced laterally. The intrapatellar pad of fat was retracted proximally to expose the bone just above the tibial tuberosity.

The entry point was about 1.5 cm distal to the knee joint and in line with the centre of the medullary canal. The tip of a curved bone awl was kept over the entry point. Medullary cavity was entered by penetrating the cancellous bone of metaphysis with the awl which was directed perpendicular to the shaft when it first penetrated the cortex, but gradually was brought to a position more parallel to the shaft as it was inserted more deeply to prevent violation of the posterior cortex. The entry point may be widened with the help of reamers.

A ball-tipped guide pin was inserted into the proximal fragment up to a position just proximal to the fracture site. Now an assistant held the fracture reduced by manipulation and longitudinal traction in line of the tibia. A curved tipped guide wire was used to aid in reduction in difficult fractures. The guide wire was now passed through the fracture site and into the distal fragment to within 1 cm of ankle joint.

The ball-tipped guide rod was exchanged for one with a smooth tip for nail insertion. The length of the nail was determined by placing the tip of a guide wire of the same length at the most distal edge of the entry portal and then subtracting the length of the overlapped portions of the guide rods from the full length of the guide rod to determine the length of the nail, making sure the fracture is held out to length during this measurement.

The insertion device and locking screw guide wire were attached to the nail. The apex of the proximal bend in the nail was directed posteriorly and the drill guide was mounted to direct screws from medial to lateral. Rotational alignment of the limb was evaluated by aligning the iliac crest, patella, and second ray of the foot. The nail assembly was inserted with moderate manual pressure and with a gentle back and forth twisting motion. Guide rod was removed after the nail passes through the fracture site and before final seating of the nail to avoid incarceration. It was aimed that the proximal end of nail should lie 0.5cm below entry portal upon final seating of the nail. The distal tip should lie 0.5 to 2 cm of the ankle joint. Distal fractures required nail insertion near the more distal end of this range.

Distal locking was performed with locking screw guide. If the distal jig failed, locking was tried with a free hand technique. If locking could not be done then, locking was planned electively later, to buy some time for soft tissue reconstruction.

Now the fracture site was inspected for possible distraction. If the fracture was found to be distracted, it was impacted by carefully driving the nail backward while watching the fracture.

Proximal locking was done with the help of the jig attached to the nail insertion device. The drill sleeve was placed through a small incision down to the bone. Both the cortices were drilled with a drill bit. The length of the bolt was measured with a depth gauge. The bolt was inserted with a hexagonal screw drive. The bolt should protrude approximately 5mm beyond the far cortex. The second bolt was inserted in more unstable fractures. Dynamic interlocking was performed in fractures deemed to be stable.

The wound was washed with saline. The surgically incised wound was sutured. Sterile dressing was applied. Compression bandage was given.

B) SOFT TISSUE RECONSTRUCTION – TECHNIQUES

METHODS OF RECONSTRUCTION

1. Skin graft
2. Local flaps
3. Distant flaps
4. Free flaps

Skin graft

Transfer of skin from one anatomical site to another with total severance of its blood supply which relies for its survival, solely on the blood supply from the recipient site.

Flaps

Transfer of tissue from one anatomical site to another with intact blood supply. Flaps are vascularised tissue possessing an arterial and a venous system. They remain attached to one or other parts of the body (retain their vascularity) during its transfer or transplant from the donor to the recipient area.

Planning of the flap

- Dimension of tissue loss (skin, subcutaneous tissue, muscle and bone) is assessed first.
- Decide about the reconstructive procedure required.
- A flap should always be planned 20% larger than the required size.

Clinical application of flaps in leg defects

Flaps are useful to close defects too large for primary closure and where skin grafts are not possible. Flaps can contain more than one type of tissue (compound flaps) and are named based upon the tissues they contain.

Fasciocutaneous flaps

This includes skin, subcutaneous tissue and the deep fascia. It is based on the fasciocutaneous vascular system.

Muscle and musculocutaneous flap

Muscle flap consists of a muscle based on a vascular pedicle and then the muscle flap is covered with a skin graft.

Musculocutaneous flap consists of skin, subcutaneous tissue, deep fascia and the underlying muscle, based on the musculocutaneous vascular system.

Advantages

- Increases the vascularity to the recipient site resulting in (a) better healing of fracture (b) enhanced action of systemic drugs (c) reduction exudate.
- Fills the defect cavity.
- Effective for contaminated or ischemic defects, because of better vascular perfusion of muscle.
- Provides good cushion over bone.
- Easy to plan as there are several muscle masses in the adjacent area.

Richard et al showed in animal models that muscle flaps significantly increase the blood flow, cortical porosity and intracortical formation of new bone.

Holden et al tested this concept experimentally and successfully demonstrated the importance of surrounding muscle in contributing vascular ingrowth to the injured bony cortex.

Complications

- Functional disability.
- Muscle necrosis due to pressure dressing, tension, arterial disease, hematoma.

Neurocutaneous flaps These flaps are considered as axial pattern flaps based on the vascular supply of the sensory superficial nerves which contribute greatly to the vascularisation of skin.

Distant flaps

When the donor area is situated at a distance from the primary defect i.e over other parts of the body, the flap is called distant flap. Distant flap can be single pedicle flap or tube pedicle flap.

Methods of transfer of distant flaps to the primary defect:

a. Direct flap transfer.

b. Indirect flap transfer.

Free flaps

These are completely detached from the donor area before being transferred to the recipient area. The vascular supply at the recipient area is restored by anastomosing the vessels of the flap to the vessels of that area using microvascular technique.

Advantages

- Single stage procedure
- Patient position in the postoperative period is more comfortable
- Period of immobilisation is shorter

- Provides option for single stage reconstruction with restoration of sensation, incorporation of vascularised bone graft or functional muscle.

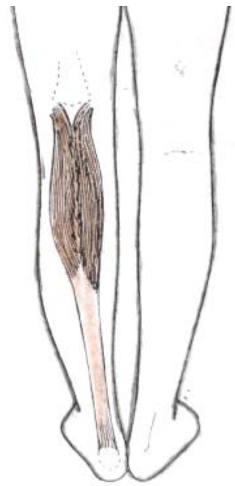
Disadvantages

- Technically difficult operation. Specially trained personnel and microvascular setup is required.
- Duration of operation is longer.

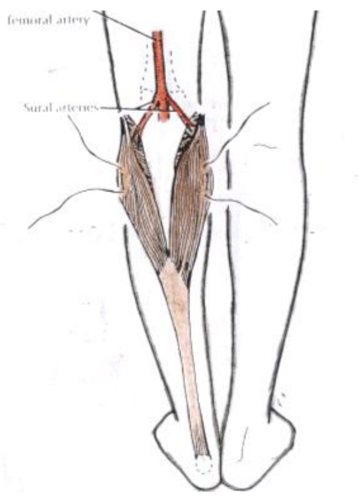
Treatment of flap necrosis

In spite of all possible measures, if the flap necrosis occurs, an aggressive approach is preferred for its management. If adequate viable length of the flap is available, the necrosed tissue is excised and reinsert is given. If this is not possible due to short flap, a more conservative method is required. We wait till flap necrosis is well demarcated and then necrosed tissue is excised. The defect produced due to excision is resurfaced by skin graft or flap later on.

GASTROCNEMIUS



The gastrocnemius is the most superficial and largest calf muscle. It has a lateral and medial head and lies superficial to the plantaris, popliteus, and soleus muscles. The medial head is larger and extends a greater distance inferiorly. The two heads unite and joint the tendon of the soleus to form the Achilles tendon.



Origin: Medial head – medial condyle of femur; lateral head – lateral condyle of femur

Insertion: Calcaneus through the Achilles tendon

Nerve Supply:

Motor – Branches of tibial nerve. The paired motor nerves enter the proximal heads of the gastrocnemius muscle in the popliteal fossa adjacent to the vascular pedicles.

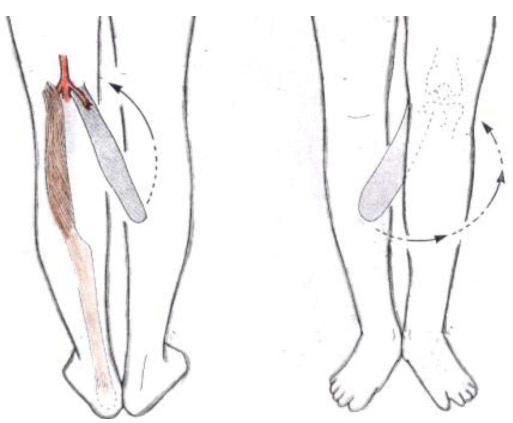
Function: Plantar flexion of the foot. With the soleus intact, one head of the gastrocnemius can be used without creating any significant functional disability.

Blood Supply

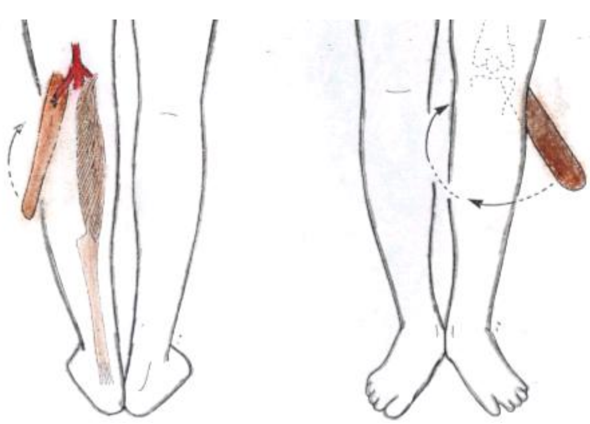
Each head of the gastrocnemius has a dominant vascular pedicle, the sural branches of the popliteal artery. These are large vessels entering each head proximally close to the origin of the muscle at the level of the femoral condyles. The vessels divide in the muscle and run longitudinally parallel to the muscle fibers. Each head has an independent vascular unit. Musculocutaneous perforators through the muscle portion of the gastrocnemius supply the overlying skin and part of the skin lying over the Achilles tendon. There are no perforators through the Achilles tendon into the overlying skin.

Arc of rotation (medial / lateral head)

Based on the proximal dominant pedicle, which is 4 to 5cm above the popliteal crease, the medial / lateral gastrocnemius head may be transposed as a muscle or musculocutaneous unit to cover the knee or the upper third of the leg. A slightly greater are of rotation can be obtained by division of the muscle origin and rotation of the muscle as either a muscle or musculocutaneous island unit.

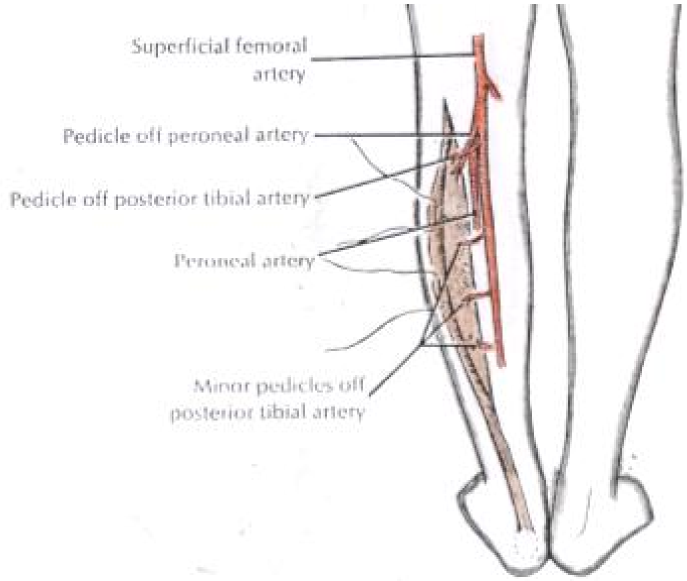


Medial head



Lateral head

SOLEUS



The soleus is a large, broad, flat muscle lying immediately deep to the gastrocnemius muscle. The muscle fibers converge into an aponeurosis that joins the tendon of the gastrocnemius to form the Achilles tendon.

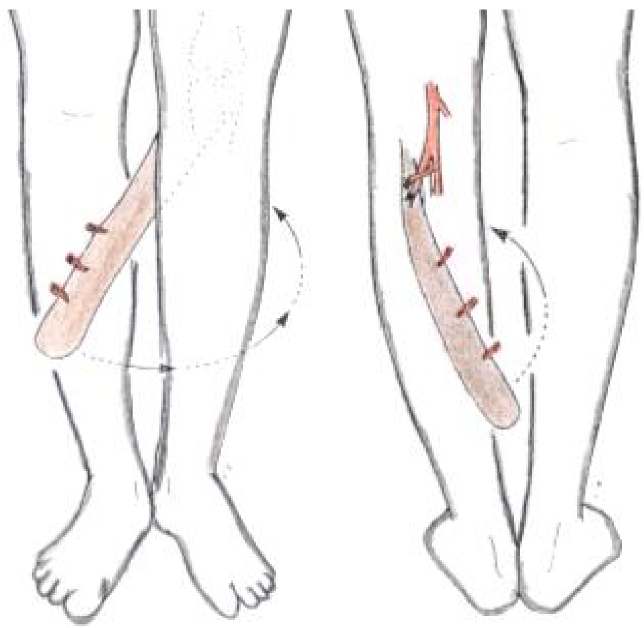
Origin: Fibular – posterior aspect of head and upper third of fibula; tibial popliteal line on posterior aspect of tibia.

Insertion: Calcaneus through the Achilles tendon.

Nerve Supply:

Motor : Branches of tibial nerve. The posterior tibial nerve lies deep to the soleus muscle along the entire muscle belly. The motor branches enter the proximal deep muscle belly.

Function: Plantar flexion of the foot. If the gastrocnemius is intact, the transposition of this muscle will not cause any significant disability in an ambulatory patient.



Arc of rotation

With the distal pedicles from the posterior tibial artery ligated, and based on the proximal pedicles from the posterior tibial and peroneal arteries, the muscle can be transposed medially or laterally to cover the middle third of the leg. This area of coverage anteriorly is located between the arc of rotation for the gastrocnemius superior and the flexor digitorum longus inferiorly. The point of rotation is about 10 to 12 cm below the knee. By incising the epimysium, the muscle can be expanded to cover a larger area.

MATERIALS AND METHODS

All adult patients, who were seen at Government Rajaji Hospital, Madurai because of an open fracture of the tibial diaphysis between July 2005 and July 2007 were evaluated for inclusion in the present study. Approval from the hospital ethics committee was obtained before the investigation was begun, and the patients gave informed consent before they were entered into the study.

Criteria for selection of patients

Inclusion Criteria

1. Age more than 20 yrs
2. Presenting within 24 hours of injury
3. High grade open tibial diaphyseal fractures (Grade IIIA, III B)
4. Primarily reconstructable soft tissue injury.

Exclusion criteria

1. Open growth plates
2. Intraarticular fractures extending into upper or lower end of tibia.

3. Fractures in the proximal fourth of tibia or fracture within four centimeters of the ankle, neither of which was judged to be amenable to intramedullary nailing
4. Grade III C fractures
5. Grossly contaminated and damaged wound.
6. Refusal for inclusion in the study

41 patients who have sustained high grade (Gustilo Anderson III A and III B) open tibial fractures fitting in the inclusion criteria entered into the study (36 males and 5 females). Their mean age was 33.95. The most common mode of injury was road traffic accidents.

They were randomly allotted into study (interlocking nailing and primary soft tissue reconstruction) and control (external fixation and delayed soft tissue cover). About 4 patients lost for follow up, and the study conducted among the 37 patients.

A standard management protocol was used in all patients. On admission, initial attention given to resuscitation and assessment of the patient according to guidelines of advanced trauma life support. Other pulmonary / abdominal / head injuries ruled out and concomitant long bones/ pelvic fractures ruled out. Thorough inspection and palpation of the limb done. Neurovascular deficits identified.

Antibiotics in the forms of cephalosporins and aminoglycosides were given intravenously immediately on admission. Coverage for anaerobic organism, with penicillin is given when possibility of infection with clostridia suspected. Tetanus prophylaxis is given.

Thorough wound wash given with sterile saline solution. Plastic surgeon opinion sought and the soft tissue status of the wound analysed meticulously with him. Wounds with primarily reconstructable soft tissue status were selected for study and allotted randomly into study or control group.

In the operating room, thorough wound irrigation and debridement done along with plastic surgeon. After skeletal stabilization, plastic surgeon proceeded with soft tissue reconstruction in study group (immediate reconstruction). If immediate reconstruction was not practical, reinspection was done within 24-72 hrs and reconstruction done (early reconstruction). In case of control subjects repeated debridements were done until the wound bed is found healthy and soft tissue coverage done later (delayed reconstruction).

Post operative regimen

After the surgery, active movements of toes, ankle and knee joint were encouraged from day one. Weight bearing (from the toe touch to partial wt bearing to full) increased as soon as possible depending upon the stability of fracture and signs of healing.

Intravenous antibiotics given for five days, wound swab for culture taken from areas of superficial and deep tissues and antibiotics switched over accordingly.

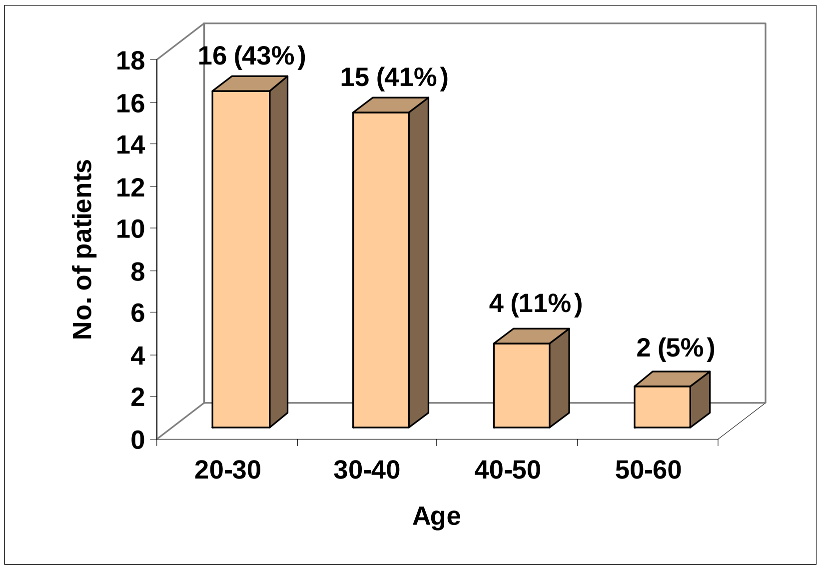
All patients were followed up every 2 weeks for 6 weeks and then monthly. A fracture was deemed to be united when the patient could fully weight bear with no pain at fracture site and there is radiographic evidence of bridging of 3 / 4 cortices in anteropostero lateral views. Union is said to be nonunion if it is not united 9 months after surgery or shows no progressive signs of healing for 3 months.

Secondary bone stimulating procedures were done whenever problems of union were considered likely.

Malunion was defined as any angulation in excess of 5° on radiograph, shortening an excess of 1 cm or rotation deformity of 15° on clinical measurement in comparison with normal side.

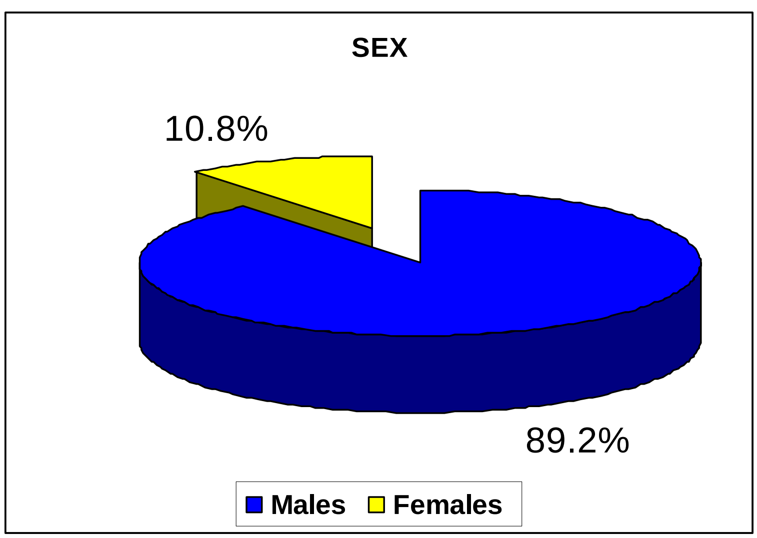
OBSERVATION RESULTS

1. Age



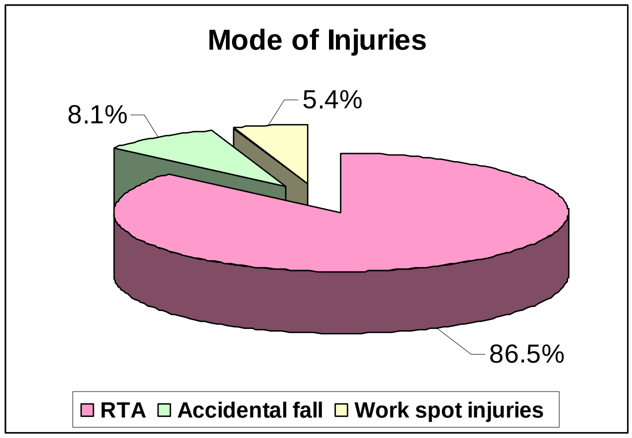
The mean age is 33.95% indicating high incidence of these fractures in productive age group and range is from 24 to 58.

2. Sex

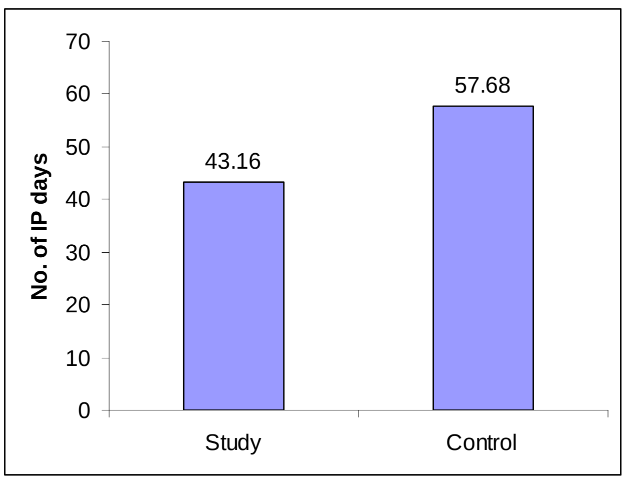


There is high incidence of these fractures in males

3. Mode of injuries



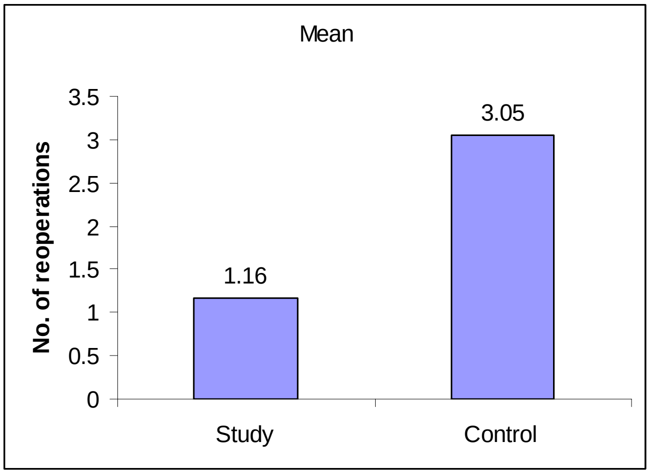
4. Number of days of hospital stay & secondary procedures



	N	No. of days	Mean	S.D.
Study	18	777	43.16	9.2
Control	19	1096	57.68	7.8

p = 0.0006 significant

5. No. of secondary procedures



	N	No. of days	Mean	S.D.
Study	18	21	1.16	8.47
Control	19	58	3.05	3.98

p = 0.0002 significant

There is a significant difference between the study group and control group with regard to number of days of stay in the hospital and number of secondary procedures.

6. Superficial infection

	Present		Absent		Total	
	No	**%**	**No**	**%**	No	%
Study	3	16.6	15	63.4	18	49
Control	4	21	15	79	19	51
Total	7	19	30	81	37	100

p = 0.0957 **Not significant**

There is no statistically significant difference between the occurrence of superficial infection in study and control group.

7. Deep infection

	Present		Absent		Total	
	No	**%**	**No**	**%**	No	%
Study	1	5.5	17	94.5	18	49
Control	4	21.0	15	79	19	51
Total	5	13	32	87	37	100

p = 0.0018 **SIGNIFICANT**

The high incidence of deep infection in control group is statistically significant.

8. Flap necrosis

	Present		Absent		Total	
	No	**%**	**No**	**%**	No	%
Study	2	11.1	16	88.9	18	49
Control	2	10.5	17	89.5	19	51
Total	4	10.8	33	89.2	37	100

p = 0.425 **Not significant**

The incidence of flap necrosis is statistically insignificant.

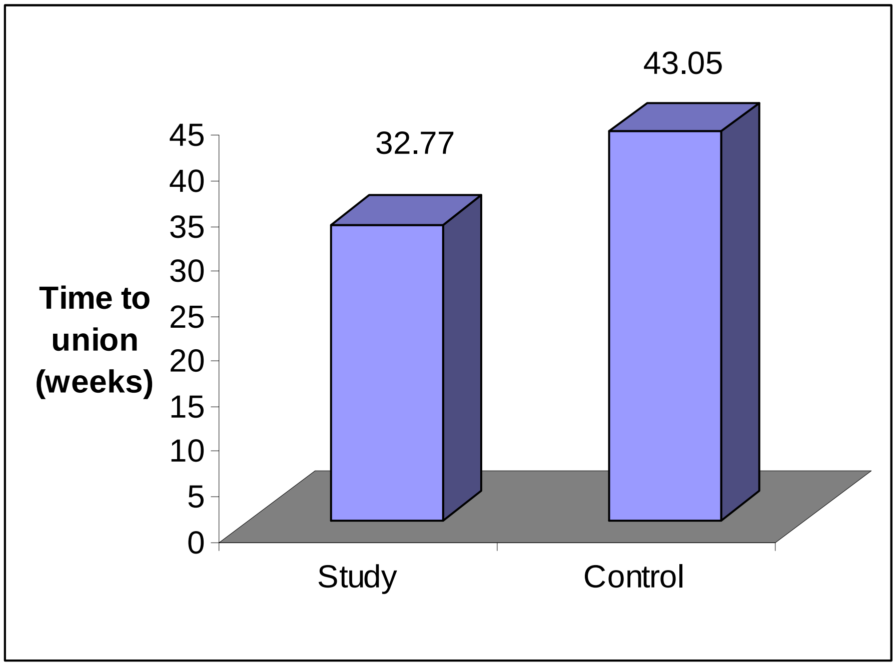
9. Non union and Mal union

Non union	**Present**		**Absent**		**Total**	
	No	**%**	**No**	**%**	No	%
Study	1	5.5	17	94.5	18	49
Control	3	15.8	16	84.2	19	51
Total	4	10.6	33	89.4	37	100

p = 0.0015 **SIGNIFICANT**

There is statistically significantly high incidence of nonunion and malunion is control group.

10. Time of union



	N	No. of weeks	Mean	SD
Study	18	590 wks	32.77	7.8
Control	19	818 wks	43.05	10.2

P = 0.0008 significant

There is statically significant delay in the bony union of control group as compared to that of the study group.

DISCUSSION

PRINCIPLES OF MANAGING OPEN TIBIAL FRACTURES AND ITS EMERGING TRENDS

1. Treatment in the Emergency Room

In the emergency room, initial attention should be given to resuscitation and assessment of the patient according to the guidelines of Advanced Trauma Life Support[30]. Specific assessment of the extremities other than to control active hemorrhage should be part of a secondary survey. The orthopaedist must be aware of other injuries because severe pulmonary, intra-abdominal, or head injuries may limit the extend of initial debridement and stabilization that can be performed acutely for the open tibial fracture[28]. Concomitant fractures of the long bones and unstable fractures of the posterior part of the pelvic ring associated with hemodynamic instability should be studied immediately.

The physical examination should include a thorough inspection and palpation of the extremities[31]. Occult fractures may be missed if the examining physician does not elevate the extremity and inspect it circumferentially. The initial evaluation should include assessment of the neurovascular status, the soft tissue injury, and the osseous deformity. The vascular status can be documented by palpation of pulses, examining for capillary refill, and notation of the color of the limb and the presence of bleeding from open wound. Osseous deformity should be evaluated. Legs that have a gross rotational deformity or angular deformity or both, at the site of a tibial fracture should be realigned promptly in an anatomical position. Associated deformities of the foot, ankle, knee, or femur should also be noted. Pulses should be documented before and after alignment. The pulses often improve with realignment; persistently diminished pulses may indicate vascular injury and the need for arteriographic evaluation. Gross motor function and sensibility of the leg should be documented whenever possible. The presence or absence of plantar sensation can be important factor in the determination of whether a limb-salvage procedure is the best treatment for a limb threatening injury.

Often, soft-tissue injuries can be assessed only superficially in the emergency room. Knowledge of the history of the injury and its location is often helpful when determining the extent of soft-tissue damage and the level of contamination. Blistering, contusions, crushed areas of skin, and burns reflect the transfer of large amount of energy to the limb. Gross contamination with soil, grass, or other foreign material should be noted. The dimensions and location of all open wounds should be recorded. A photograph of the open wound helps to document its characteristics. Extensive or contaminated wounds should be lavaged profusely with sterile saline solution. Superficial foreign bodies, such as leaves and grass that are immediately accessible should be removed from the wound before it is sealed. The surgeon should take care not to increase the contamination of the wound during the initial inspection phase. A clean sterile dressing should be applied to the wound and should not be removed until the patient is taken to the operative room. The limb should be placed in a well padded plaster splint in grossly normal alignment.

Early intravenous administration of antibiotics is associated with a decreased rate of infection and thus should be begun in the emergency room[31]. Coverage for gram-positive organisms with cephalosporins should be routine for all open fractures. Coverage for gram-negative organisms typically with an aminoglycoside, is used for open fractures with more extensive soft-tissue injury or extensive contamination, or both. Coverage for anaerobic organisms, typically with penicillin, should used whenever thee is the possibility of infection with Clostridium perfringens, such as from contamination with soil (particularly with injuries that occur on a farm) or public waters such as rivers or lakes. Antibiotic therapy should be continued for forty-eight to seventy-two hours after the initial debridement type –I and type –II open fractures, as classified by Gustilo and Anderson. Antibiotics should be given as long as 120 hours after debridement of a type-III open fracture.

Prophylaxis against tetanus should also be considered with any open fracture. Patients who were immunized in the last five years before the injury do not need prophylaxis. Those who were immunized more than five years before the injury should receive a tetanus booster. Patients for whom the time of the last immunization is unknown or who have never been immunized should receive a tetanus immunization booster as well as tetanus immune globulin. The usefulness of culture before and after debridement is doubtful, as revealed by the studies so far.

2. Initial operative treatment

An open tibial fracture is an operative emergency. The primary treatment is early operative debridement and stabilization of the bone. Debridement of an open tibial fracture involves operative exploration of the wound or wounds to define the zone of injury, removal of devitalized tissue, and use of pulsed lavage to achieve additional mechanical debridement of the wound[31]. Experience and judgement are required to determine the appropriate extent of debridement. The wound should be extended with the use of sharp dissection until healthy tissue is seen at each end. The wound should then be explored systematically to ensure complete debridement of all contaminants and devitalized tissue.

Debridement should begin with the skin. After operative extension, the edges of the skin should be inspected carefully about the entire wound. Evidence of skin and subcutaneous tissue that has been avulsed from the underlying fascial structures should be noted as this is an indicator of high-energy trauma and maybe indicative of underlying muscle injury. The debridement should continue in a methodical way with careful inspection of the subcutaneous tissue, muscle, and finally bone to avoid overlooking any devitalized tissue. The skin and subcutaneous tissue are inspected throughout the entire extent of the wound. Any obviously non-viable or crushed skin should be excised. Skin with questionable viability can be retained a later debridement. This is especially important in the area of the subcutaneous border of the tibia, injudicious removal of skin may necessitate later use of a local or distant flap to cover the bone[31].

Muscle should be inspected carefully for signs of viability, which can be assessed with the so-called four C's color, consistency, contractility, and capacity to bleed[31]. Of these four, the latter two, particularly contractility, are the more sensitive indicators of viable muscle. Clearly non-viable muscle should be debrided. Muscle that is weakly contractile and appears contused can be left and reinspected in 24-72 hours. Attempts should be made to maintain the integrity of musculotendinous units whenever possible without compromising the debridement. It must be remembered that the presence of an open injury does not preclude the development of a compartment syndrome, and fasciotomy of the compartment / compartments containing structures that may have been damaged by the injury through the open fracture wound should be performed routinely as part of the initial debridement. However, fasciotomy of all compartments should be reserved for injuries with extensive soft-tissue swelling and increased intracompartmental pressures (to within twenty to thirty millimeters of mercury). The more extensive use of fasciotomy may be warranted for patients having moderate swelling of the leg, for those who have sustained systemic hypotension, for those with polytrauma in whom an accurate clinical examination may be difficult postoperatively, or after revascularization for salvage of the limb.

Bone that is stripped of all soft-tissue attachments is necrotic and can act as substrate for organisms to cause infection. Small-to-moderate avascular segments of bone should be removed. The decision to debride large portions of devascularized diaphyseal or metaphyseal bone, or both, is often a difficult one. Major articular segments of the tibial plateau and the tibial plafond should be retained, even when there is extensive stripping, if the surgeon believes that salvage of the involved joint is possible. Areas of bone that have been stripped of periosteum but that are in continuity with a vascularized portion of the tibia can be retained if there is adequate soft tissue coverage to allow early revascularization. Debridement of free segments of devascularized diaphyseal bone has been reported to result in a decreased prevalence of infection. The retention of completely free segments of devascularized diaphyseal or metaphyseal bone should be considered only rarely. The surgeon should be aware that the risk of postoperative infection is higher when necrotic bone remains in the wound.

With regard to irrigation, high pressure pulsatile lavage appears effective, but recently challenged due to its risk of bone damage and deeper bacterial penetration. Recently, investigators found that antiseptic solutions of hydrogen peroxide, Betadine (povidone iodine) solution, and Betadine scrub are toxic to osteoblasts in culture at concentrations used clinically and bacitracin in normal saline solution had no similar toxic effects[32].

3. Stabilization of open fractures

After the initial irrigation and debridement, the next step is stabilization of the osseous injury. Controlling instability of the bone provides several benefits: continued damage to the surrounding soft tissue by displaced bone fragments is decreased, care of the soft-tissue injuries is facilitated, and the patient's comfort is increased. Options for stabilization include immobilization in a cast, external fixation, internal fixation with plates of screws, and intramedullary nailing. Immobilization of open fractures in a cast is associated with an increased prevalence of non-union and delayed union (ten of 205 to forty-five of 112 fractures in reported series) as well as late osseous deformity (seventeen of thirty-three fractures in reported series)[31].

External fixation offers several advantages in the treatment of open tibial fractures. Most of external fixation frames provide acceptable stability for such fractures. Generally, there is good access the soft tissues, and most forms of external fixation do not substantially impair the range of motion of knee or ankle. External fixation is typically applied as a static form of immobilization to maintain skeletal alignment. Newer forms of external fixation allow compression of the fracture site with weight-bearing.

External fixation has also been associated with many difficulties. Irritation of the pin track with inflammation of the skin at the interface between the bone and the pin is a common problem that can present in many ways, ranging from mild erythema about the pin to a frank pin-track infection. Pin-track infections are associated with thermal necrosis of bone at the time of insertion of the pin. Green and Ripley[33] reported fourteen cases of osteomyelitis that occurred in the tracks of pins that had been placed entirely in cortical bone. Infection can be avoided by predrilling pin tracks and by not placing the pin entirely through bone.

External fixator pins have a limited life span and typically loosen between three to six months and application of the fixator, necessitating either revision of the fixator or conversion to another form of treatment. Iliac-crest bone-grafting early (within the first six weeks) after the injury frequently is recommended to accelerate union of the fracture before the fixator becomes loose. Delayed conversion of an external fixator to an intramedullary nail has been associated with an increased prevalence of infection. Mc Graw and Lim[34] found an infection around seven of sixteen open fractures the tibial shaft that had been treated with external fixation followed by intramedullary nailing. The authors found that a pin-track infection during the course of external fixation is the most sensitive predictor of infection after intramedullary nailing. Fractures that have been treated with external fixation for more than twenty-one days and are being considered for treatment with delayed intramedullary nailing should be assessed carefully for any history of drainage around or infection of track to evaluate the risk of deep infection.

Fixation with a plate typically is now reserved for the treatment of open periarticular fractures of the tibial plateau and selected fractures of the tibial plafond[31]. The application of a plate requires extensive dissection, which devitalizes soft tissue and may lead to more frequent complications. Ruedi et al[35] reported a prevalence of infection of 12% (twelve of 101) after fixation of open fractures of the tibial shaft with a plate. In a prospective randomized study, Bach and Hansen compared the use of external fixation with that of open reduction internal fixation with plates and screws for type-II and type-III open fractures of the tibial shaft. They found a prevalence of infection of 35 per cent (nine of twenty-six fractures) and a prevalence of osteomyelitis of 19 per cent (five or twenty-six fractures) after fixation with plates and screws, compared to external fixation.

Stabilization with an intramedullary nail has become increasingly popular for the treatment of fracture the tibial shaft. One study demonstrated a decreased prevalence of deep infection with use of Ender nails (two of twenty-nine) compared with the prevalence with use of external nails (four of twenty-eight), and there were no pin-track infections associated with the Ender nails. Similar findings were noted in a comparison of external fixation with Lottes nails[3,4]. However, the use of Ender or Lottes for axially unstable fractures often results in malunion and creates the need for prolonged immobilization.

Nailing without reaming has been advocated for open tibial fractures to minimize the injury to the endosteal circulation caused by reaming. Several authors have reported on the use of locking nails without reaming for the treatment of open fractures of the tibial shaft.

Various studies by Keating et al[11] (1997, 2000) Henley et al[12] (1998), Bhandhari et al[16] (2001), Court Brown et al[9] (2004), Gopal et al[2] (2004), [as described in review of literature section] have shown intramedullary nailing has many advantages over external fixators in treating these fractures. No external fixation pins or circumferential plaster dressing is needed, facilitating free-tissue transfer (or) local rotational flap cover. An early range of motion of knee and ankle is facilitated with intramedullary fixation. Several of the drawbacks associated with external fixation, such as pin loosening, loss of fixation, are avoided.

But it should be appreciated that both external fixation and intramedullary nailing requires technical expertise to obtain acceptable reduction and stable fixation.

Ostermann et al[36] reported a significant decrease ($p < 0.05$) in rate of infection with the help of antibiotic cement beads.

Recently, the use of antibiotics impregnated cement beats have been emerging in the use of open fractures (Bead-pouch technique). It proves to be a useful adjunct to systemic antibiotics. Potent utility of antibiotic impregnated bone grafts, bone graft substitutes and antibiotic coated nailing have yet to studied in an extensive way, so far.

4. Soft tissue management

Early intensive debridement is the fundamental principle of treating severe soft tissue injuries. High energy violence with extensive injuries should be reinspected and additionally debrided within 24-48 hrs. The goal is to remove all the necrotic tissues so that the substrate for infection is removed. Gustilo originally recommended delayed closure of wound [5 days after the debridement]. In general, soft tissue reconstruction is done only when there is a healthy soft tissue base [which may take 5-7 days in ideal conditions].

Later, Godina et al[1] recommended early flaps in severe soft tissue injuries for better results. Thereafter many studies were conducted with regard to radical soft tissue management with primary reconstruction. [**Immediate** - at the time of skeletal stabilization / within 24 hrs, **Early** - within 48 to 72 hrs].

Delong et al[13] (1999), Hertel et al[14] (1999), Gopal et al[2] (2000, 2001) Naigue et al[18] have demonstrated better results with early soft tissue construction.

Exposed tendon and bone without peritenon or periosteal coverage necessitates flap coverage. If rotational or free-flap coverage of the fracture is needed, it should be done within the first seven days the injury. Delay beyond this time has been associated with an increased prevalence of late infection. Flap coverage can be performed with a local rotational muscle flap, a free vascularized muscle flap, or fasciocutaneous flap. Muscle flaps have been shown to aid revascularization of underlying exposed bone and they are superior to fasciocutaneous flaps in the treatment of dead space caused by a loss of bone tissue. In general, tissue defects in the proximal third of the tibia are covered with a gastrocneumius rotational flap. A soleus rotational flap is recommended for defects in the middle third of the tibial shaft, a free vascularized muscle flap typically is needed for those in the distal third of the tibia. However success of a local muscle rotational flap may be precluded if the muscle to be mobilized – that is, the gastrocnemius or the soleus – was involved in the zone of injury, and severe muscle contusion preludes the local rotation of the muscle for flap coverage. In these cases, free vascularized flaps may be necessary. Delayed soft tissue reconstruction is more difficult because of tissue edema, perivascular fibrosis and increased risk of venous thrombosis.

With fasciocutaneous flap coverage, a segment of the skin, the underlying subcutaneous tissue, and fascia mobilized to cover the exposed bone or tendon, or both. Fasciocutaneous flaps are based on circulation from the posterior tibial or peroneal systems. With careful planning, a flap with as high as a 3:1 length width ratio can be created safely, while a 1:1 ratio is necessary for random flaps. Recently, good results have been reported following treatment of open tibial fractures with fasciocutaneous flaps.

Recently, vacuum-assisted closure (V.A.C.)[29] has emerged as a useful method in accelerating wound healing by reducing edema, increasing local blood flow and enhancing granulation tissue formation.

5. Bone Grafting

Early iliac-crest bone-grafting is recommended for fractures with extensive soft-tissue stripping, especially those treated with external fixation, as well as fractures with a loss of more than 50 per cent of the circumference of the bone or areas of segmental loss. The bone-grafting should be performed after soft-tissue coverage has been achieved. Fischer et al. reported that bone-grafting of type-IIIA and III B fractures before a healed soft-tissue envelope was present, led to an infection in four of fifteen patients, whereas delayed bone-grafting performed after a well vascularized soft-tissue envelope was present (six to eight weeks after fracture) did not lead to an infection in any of the sixteen patients who were managed in this fashion. Grafting should be considered for type –IIIB fractures that are not associated with a loss of bone if there is no callus three months after injury.

Recently, evidence has emerged regarding the use of recombinant human bone morphogenic protein (rhBmp-2)[29]. In a multicentre, prospective trial of 450 open tibial fractures, rhBmp-2 implants were found to significantly reduce the risk of secondary procedures and better fracture healing. While additional studies are certainly required, there appears evidence in support of use of rhBmp-2 in open fractures, especially of severe grade.

6. Rehabilitation

Early functional rehabilitation should be a key part of the treatment of open tibial fractures. Physical therapy programs to emphasize the range of motion of the knee and ankle are critical in the first few weeks after the injury. The patient should be encouraged to maintain good muscle tone, even if no weight-bearing or only toe-touch weight-bearing is allowed. Patients who have an axially stable fracture pattern can begin bearing weight immediately, whereas those who have an axially unstable fracture pattern should delay weight-bearing until the first callus is seen. Patients who have a fracture with segmental bone loss should not be allowed to bear weight on the affected extremity until there are radiographic signs of incorporation bone graft (callus).

INFERENCE

Age and Sex distribution

The mean age of the patients in the present study was 33.95. Majority of the patients were male accounting for 33(89.2%) cases.

Mode of injury

The leading cause of the injuries was road traffic accident in the present study accounting for 32 (86.5%) of cases. Others causes included accidental falls and work spot injuries, accounting for 3 (8.1%) and 2 (5.4%) respectively. This indicates that the incidence of open fractures can be brought down by road safety measures.

Duration of between injury and surgery

Numerous studies have stressed on early Debridement and stabilization of open fractures of tibia. Some recent reports have questioned this belief. Shanker et al stated that incidence of complications correlates more with the severity of the injury rather than with time form injury to treatment. In our study, the patients were taken into theatre for Debridement and skeletal stabilization at an average of 15.46 hours.

There is no statistically significant difference in the outcome between immediate (within 24 hrs) and early (between 24-72 hrs) reconstruction, but there is statistically significant difference between primary reconstructions (within 72 hrs) and delayed (after 72 hrs) soft tissue reconstructions.

Approach and knee pain

Anterior knee pain after intramedullary nailing is common. Dissection of the patellar tendon and its sheath during nailing is thought to be a contributing cause. It may be also due to a protruding nail, heterotopic ossification of patellar tendon, injury to menis (or) ligaments. If knee pain is severe, nail removal is needed.

In our study, only two patients had moderate anterior knee pain, which subsided after analgesics.

Nail size and locking

Average diameter of nail used was 8.50mm. Majority of nails were of 9mm. Both proximal and distal locking were done. As the study involves high grade open tibial fractures, reaming was not done routinely, though the controversy of reaming in open tibial fractures continues. Screw breakage occurred in two patients and it was asymptomatic and considered as autodynamization.

There was no case of compartment syndrome, fat embolism (or) peroneal nerve palsy in the present group.

Soft tissue healing

Superficial infection

The incidence of superficial infection (p = 0.0957) in both groups is statistically insignificant, indicating that these high grade violence is prone for infection, despite following strict protocols. These infection subsided once treated with appropriate culture and antibiotics.

Deep Infection

The high incidence of deep infection in control group (4 out of 19) when compared with study group (1 out of 18) is statistically significant (p = 0.0018). The prevention of infection depends on several factors. We believe that our low rate of infection in study group is associated with the adequacy of the Debridement, skeletal stabilization with intramedullary nailing and subsequent obliteration of the dead space by a healthy, well vascularised and conforming muscle flap.

There was one care of chronic osteomyelitis in control group for which repeated debridements were done. There is also high incidence of pin tract infection (6 out of 19 patients) exclusive to external fixation.

These high incidence of deep infection, pin track infection in control group 19 attributable to the bare tibia devoid of periosteum left uncovered which worsens the vascular status of the fractured surfaces, leading to bone necrosis and nosocomial contamination.

Flap Necrosis

Flap necrosis occurred in both the study and control group (two in each group), and they were statistically insignificant. This shows that early flap cover, if carefully done following the protocols and principals can come with better results as delayed soft tissue cover is more difficult because of tissue oedema, perivascular fibrosis and increased risk of venous thrombosis.

Union

There is statistically significant ($p = 0.0008$) delay in union of external fixator and delayed cover group (Mean = 43.05 wks) when compared with study group (Mean = 32.77 wks). There is also significant increase in the number of Malunion and nonunion ($p = 0.0015$). The early union in study group is attributable to the biomechanics of intramedullary nailing, early soft tissue cover nourishing the fracture surface, and adequate bone grafting whenever union seemed to be delayed.

Secondary procedures

There is a statistically significant ($p = 0.0002$) high requirement of secondary procedures in control group (mean = 3.05) when compared with study group (mean = 1.16). Along with delayed soft tissue cover and fixator removal procedures, which are a must for all control groups, they also needed repeated debridements due to high incidence of deep infections.

Our results have shown that aggressive management of severe open tibial fracture of the tibia was effective. We accept that this approach is radical, and that it has been claimed that immediate soft tissue cover is not safe. However analysis of our cases shows excellent soft tissue healing, lower rates of infection and better bony union, supporting the concept that delay is not necessary if healthy soft tissue can be imported reliably into the zone of injury.

CONCLUSION

Open tibial shaft fractures represent a severe and complex problem and optimal management is essential if the patient is to regain significant preinjury level of functions.

Soft tissue management including emergent irrigation and debridement of the wound and administration of antibiotics are of utmost importance in the treatment of these fractures.

High union rates, low incidence of complications including infection and good functional results suggests that primary interlocking nailing and soft tissue reconstruction is a safe and effective technique for high grade open tibial fractures.

Modern techniques of management combining the skills of experienced orthopaedic and plastic surgeons can consistency restore excellent limb function in a very high proportion of patients.

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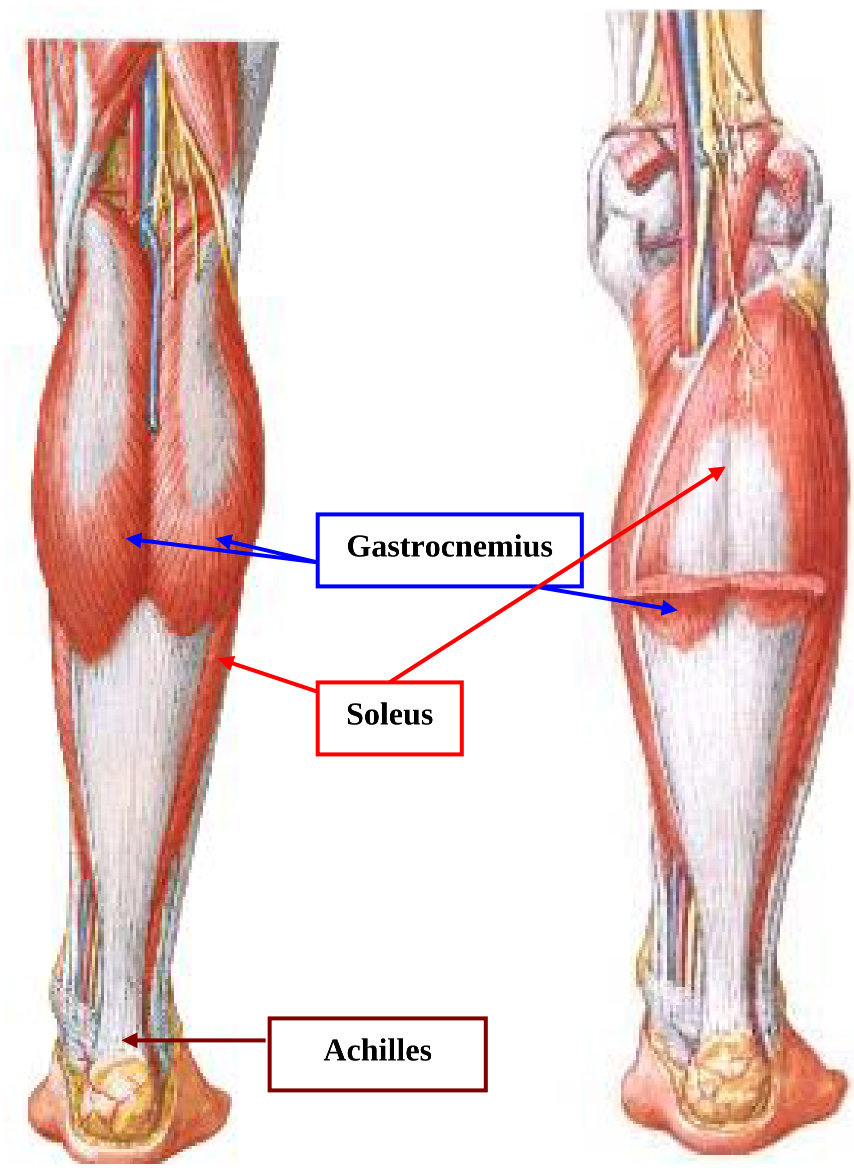
ABBREVIATIONS

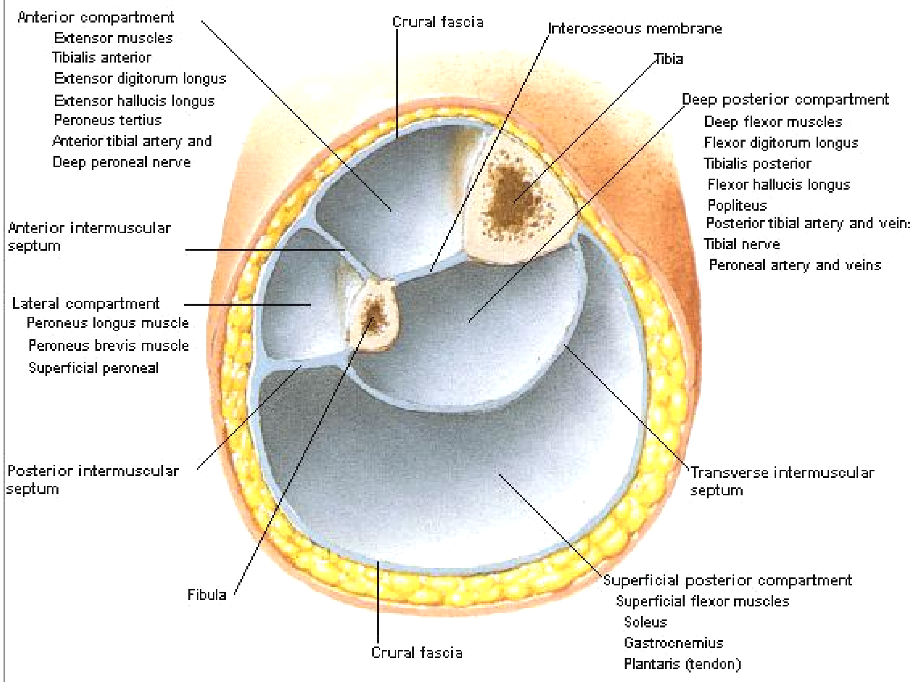
MGMP	-	Medial Gastrocnemius Myoplasty
FCF	-	Fasciocutaneous Flap (SB – Superiorly Based)
		(IB – Inferiorly Based)
SSG	-	Split Skin Graft
LGMP	-	Lateral Gastrocnemius Myoplasty
MG MCF	-	Medial l Gastrocnemius Myocutaneous Flap
RSAF	-	Reverse Sural Artery Flap
PBF	-	Perforator Based Flap
AKP	-	Anterior Knee Pain
DU	-	Delayed Union
DL	-	Distal Locking
BG	-	Bone Grafting
SFI	-	Superficial Infection

MUSCLES OF LEG POSTERIOR VIEW



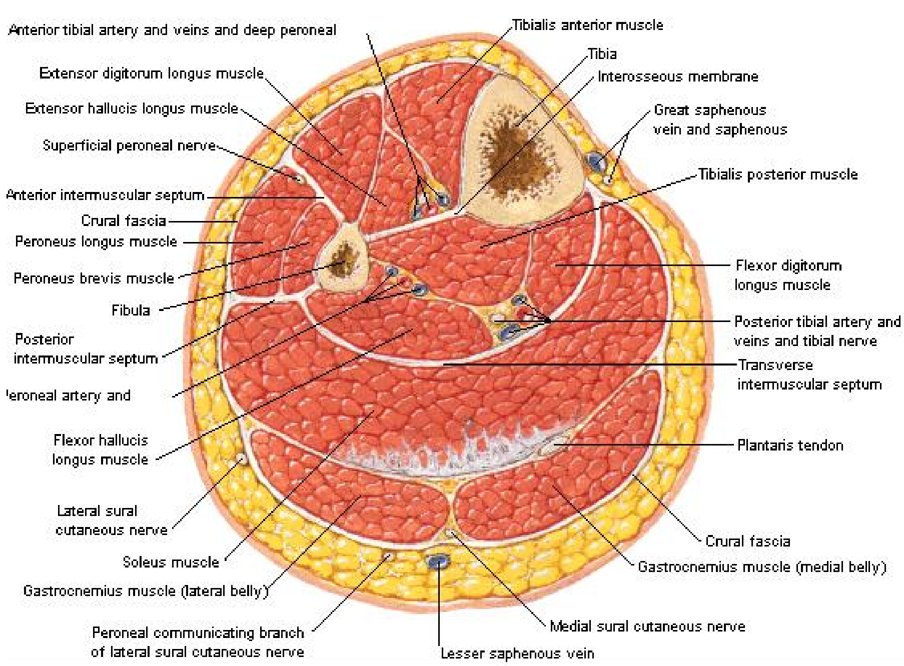
Leg

Cross Section - Fascial Compartments



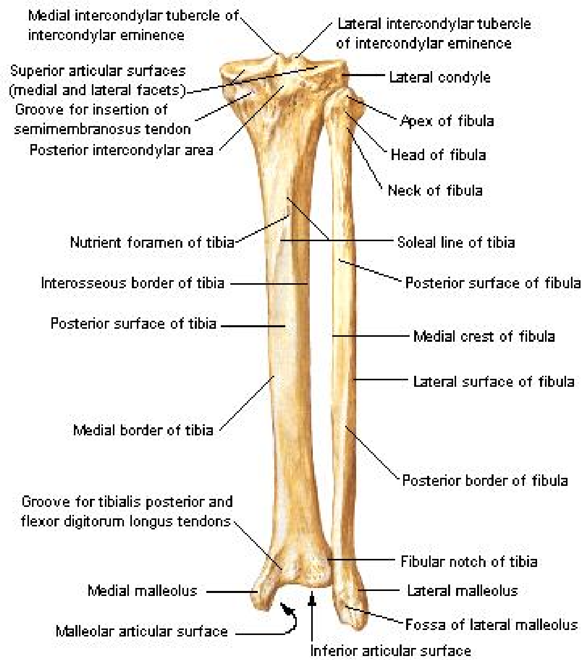
Leg

Cross Section just above Middle of Left Leg



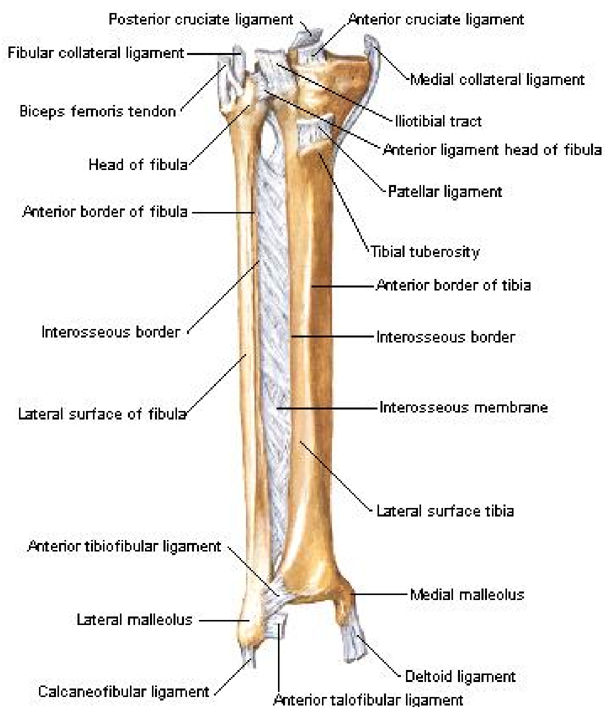
Tibia and Fibula of Right Leg

Posterior View



Tibia and Fibula of Right Leg

Anterior View - Ligament Attachments



SUBBIAH, 30/ M, COMMINUTED FRACTURE MID THIRD BB LEG PRIMARY NAILING AND GASTROCNEMIUS MYOPLASTY AND SSG DONE

Presentation

After Debridement

Primary Nailing

Gastrocnemius Myoplasty

Day 2

Primary SSG done

100% graft take – Day 5

12^{th} week

Knee – Full ROM

Ankle - Full ROM

X – ray day 1

Post op

20^{th} week

28^{th} week

RAJESH, 27/M COMMINUTED MID THIRD LOWER THIRD JUNCTION FRACTURE BB LEG PRIMARY NAILING AND SUPERIORLY BASED FASCIOCUTANEOUS FLAP

Presentation

After Nailing

Vascular status of the flap assessed by plastic surgeon

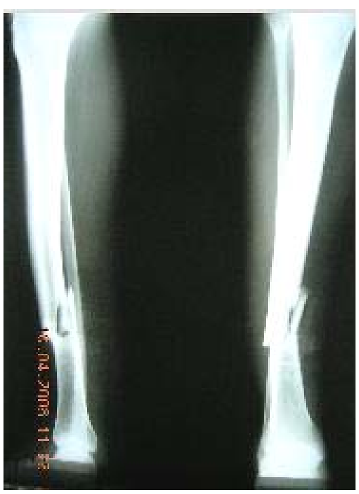
Fasciocutaneous Flap (SB)

SSG

5^{th} POD

Knee full ROM

12^{th} Week



X-ray day – 1

Post op

24^{th} Week

MUTHUSAMY, 28/M COMMINUTED FRACTURE MID THIRD BB LEG – PRIMARY NAILING AND GASTROCNEMIUS MYOPLASTY AND SSG DONE


Presentation


Gastrocnemius Myoplasty


Skin approximation


Primary SSG


5th POD – 95% Take


20th week

Knee and ankle full ROM

X-ray Day – 1

Post op

28th week

KRISHNAN, 58/M COMMINUTED MID THIRD FRACTURE BB LEG PRIMARY NAILING AND MEDIAL GASTROCNEMIUS MYOCUTANEOUS FLAP AND SSG DONE




Presentation **Medial Gastrocnemius Myocutaneous Flap + SSG** **24th week**


Full ROM


Post op **32nd week**

PALANI, 25/ M, OBLIQUE FRACTURE UPPER THIRD BB LEG PRIMARY NAILING AND FASCIOCUTANEOUS FLAP AND SSG DONE




Presentation **Superiorly Based Fasciocutaneous Flap & SSG**



5th POD **Knee and ankle full ROM**

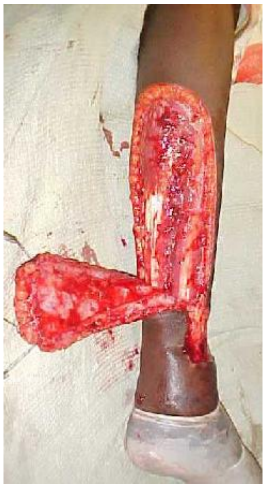

Pre op X-ray

Post op X-ray

24th week

36th week

PETCHIMUTHU, 36/M, COMMINUTED FRACTURE LOWER THIRD BB LEG – PRIMARY NAILING AND REVERSE SURAL ARTERY BASED FLAP AND SSG



After debridement

Reverse Sural Artery Based Flap

12^{th} week

Pre op

Post op

24^{th} week

36^{th} week

CONTROL GROUP – External Fixator and Delayed Soft Tissue Cover

SSG

INFERIORLY BASED FASCIOCUTANEOUS FLAP

SUPERIORLY BASED FASCIOCUTANEOUS FLAP

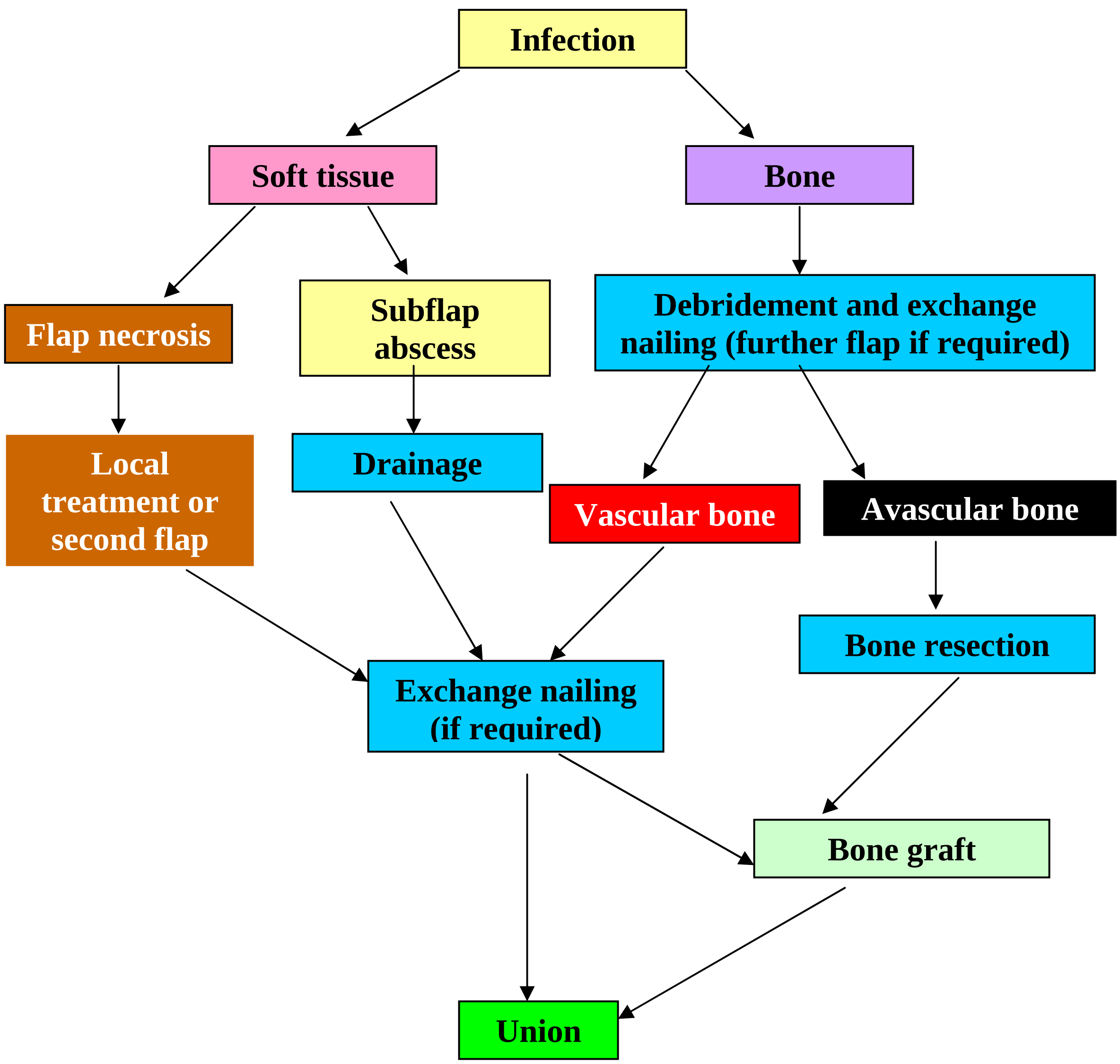
INSTRUMENTATION








ALGORITHM FOR THE MANAGEMENT OF INFECTION GUSTILO GRADE III-B FRACTURES TREATED BY REAMED INTRAMEDULLARY NAILING



MASTER CHART - CONTROL GROUP

Sl. No.	Age	Violence	Gustilo Type	Fixation	Timing (hrs)	Soft Tissue cover	Timing of Soft Tissue Cover (in days)	Complications	Secondary Procedure	Re operation	IP days	Union (wks)
1	26	RTA	III B	EF	13	FCF + SSG	5	SFI	EFR	2	45	34
2	29	RTA	III B	EF	17	MGMP + SSG	7	PTI	EFR	2	47	44
3	34	RTA	III B	EF	20	MGMP + SSG	10	-	EFR	2	32	36
4	37	RTA	III A	EF	12	SSG	8	DU	BG, EFR	3	60	48
5	29	RTA	III B	EF	12	LGMP + SSG	9	Flap necrosis, Deep inf, DU, PT	WD (2) + Trimming, SSG, BG, EFR	5	78	52
6	36	RTA	III B	EF	16	SB FCF + SSG	18	DU, Malunion	EFR	2	40	34
7	48	RTA	III A	EF	15	SB FCF + SSG	14	SFI, PTI, DU	EFR	2	65	44
8	29	RTA	III B	EF	22	SSG	12	Deep inf, Non union, PT	WD, SSG, Exchange nailing + BG, EFR	5	92	52
9	32	WS	III A	EF	17	SSG	10	SFI	WD, SSG, EFR	3	70	40
10	39	RTA	III B	EF	16	SB FCF + SSG	12	SFI, PTI, DU	WD, SSG, BG	4	64	52
11	37	RTA	III A	EF	10	SSG	8	-	EFR	2	37	38
12	27	RTA	III B	EF	7	MG MCF + SSG	26	Deep inf, PTI, DU, Nonunion, Chronic osteomyelitis	WD, SSG, BG, (2)	5	96	64
13	29	RTA	III A	EF	14	SSG	14	-	EFR	2	34	36
14	39	RTA	III B	EF	09	MG MCF + SSG	12	DU, Malunion	BG, EFR	3	68	52
15	42	AF	III B	EF	13	PBF + SSG	10	Malunion	EFR	2	39	36
16	45	RTA	III B	EF	14	MGMP + SSG	15	Flap necrosis, Deep inf, non union, PTI	WD, Trimming + SSG + Reflap, Ex. Nailing + BG	5	88	52
17	28	RTA	III B	EF	10	MG MCF + SSG	17	SFI, DU	WD, SSG, BG	3	55	40
18	29	AF	III A	EF	8	SSG	8	Malunion	EFR	2	41	34
19	38	RTA	III A	EF	10	SSG	14	-	EFR	2	45	30
Mean	**34.39**				**13.42**					**3.05**	**57.68**	**43.05**